Emotion Regulation in the Wild: Introducing WEHAB System Architecture

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Abstract
Emotion regulation in the wild (ER-in-the-wild) is an important grand challenge problem of increasing focus, and is hard to approach effectively with point solutions. We provide HCI researchers and designers thinking about ER-in-the-wild with an ER-in-the-wild system architecture derived from mHealth, the Emotion Regulation Process Model (PM), and a circular biofeedback model that can be used when designing an ER system. Our work is based on literature reviews of and collaborations with experts from the domains of wearables, emotion regulation, haptics and biofeedback (WEHAB) as well as systems. In addition to providing a generic model for ER-in-the-Wild, the system architecture presented in this paper explains different kinds of emotion regulatory interventions and their characteristics.

Author Keywords
Haptic; Emotion; Emotion Regulation; Accelerometer; Wearable; Biofeedback; Grand Challenge; Intervention;

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Introduction

Although emotions are vital for everyday human functioning, they can also be harmful when they are of the wrong type, intensity, or duration for a given situation [6]. Such observations give rise to the question of how technology affordances can assist with emotion regulation. Imagine an affordance—a vest, a wristband, etc.—that helps a person become aware of and take action to regulate the onset of inappropriate emotions. We call this "emotion regulation in the wild" (ER-in-the-wild), since engagement takes place in uncontrolled settings such as in the middle of a discussion with colleagues or interacting with the general public.

Emotion regulation (ER) refers to the processes people use to influence the type, intensity, and duration of their emotions [6]. ER is used, for example, to keep calm under pressure, or to avoid becoming overwhelmed by feelings such as anger or sadness. While emotion regulation behaviors are widespread and largely intuitive, everyone, at some point, fails to effectively regulate his or her emotions. In many cases, such failures result in misunderstandings and apologies, but as the example above illustrates, failures can also damage people and the organizations in which they work or participate. In addition, repeated failures can lead to the development of mental health disorders such as anxiety or depression [6]. Over the years, emotion regulation research has identified several reasons for such failures, such as failing to detect rising negative emotions and not selecting an appropriate emotion regulation strategy [6]. These reasons in turn suggest simple interventions that can correct the maladaptive course of emotion regulation. For example, a particular intervention is being cued, with appropriate emotion regulation strategy, thereby helping the person become aware that they are overreacting and should make an attempt to substitute an alternative behavioral approach [6].

ER is currently receiving growing attention from the Human Computer Interaction (HCI) community [4, 3, 9, 12]. Several startups have sought to address ER-in-the-wild by developing wearable technologies designed to support emotion regulation [1, 5, 15]. However, early efforts are not appropriate for ER-in-the-Wild, which is not surprising: they weren't designed to be. We argue that these designs fall short because they are not fully grounded in all four domains that are relevant to ER in the wild: emotion regulation theory, biofeedback, haptics, and wearables (we call these four domains together WEHAB, which comes from the first letters of Wearables, Emotion regulation, HAptics, and Biofeedback) [13]. With better knowledge of these WEHAB domains, designers can deploy appropriate tradeoffs across all four domains, as compared to optimizing for a smaller, incomplete set of these domains.

ER-in-the-wild has the hallmarks of a grand challenge problem: it requires a multidisciplinary approach, technological innovation, and deeper understanding of human behavior and perception. In this paper, we present a systems architecture derived by combining three models from WEHAB: an mHealth model from the domain of wearables [11, 10], the Emotion Regulation Model (PM) from the domain of emotion regulation[7], and the circular model from the domain of biofeedback[14]. This ER-in-the-Wild system architecture is derived from a literature review of the domains of WEHAB, and is also informed by consultations with practitioners and researchers from these fields. We believe that the ER system architecture derived from WEHAB domains of knowledge presented in this paper will help guide future efforts in this important problem space.

Background

Our ER-in-the-Wild system architecture relies heavily on a temporal model for ER [7], which we denote with PM. This model taken from co-author James Gross' research. According to PM, there are four stages of the emotion regulation process: identification (evaluating whether an emotion needs to be regulated or not), strategy selection (selecting an appropriate regulation strategy based on situational demands and regulation skills), strategy implementation (employing a specific tactic that implements the selected strategy: paced breathing, alcohol consumption, and exercise are all tactics of the response modulation strategy), and ongoing strategy implementation monitoring (determining whether the ongoing emotion regulation effort should be maintained, switched to a different strategy, or stopped).

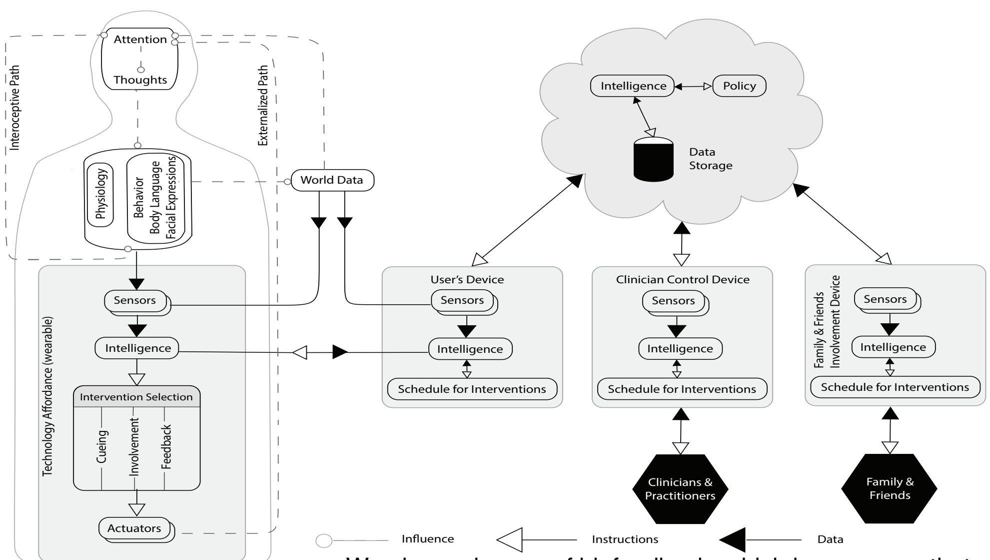

Figure 1: WEHAB Emotion Regulation in the Wild Architecture.

We also make use of biofeedback, which is a process that enables an individual to learn how to change his or her physiology through real-time physiological feedback. Simplifying, the circular model of biofeedback consists of three steps: (1) monitoring: measuring a physiological process of interest; (2) feedback: presenting what is monitored as meaningful information to the user; (3) implementation: user behavior aimed at changing the physiology and developing automatic mastery of the behavior [14].

We constructed our ER-in-the-Wild architecture with the aid of a team of experts in ER, in wearables, in haptics, in distributed systems, and in device engineering. We proposed and discussed different proposed architectures to better understand the others' understanding of the problem domain and the contribution each expertise brought to the problem. The resulting architecture presented here combines an mHealth system architecture by David Kotz [11], the PM model, and a biofeedback model.

ER-in-the-Wild System

Figure 1 illustrates our generalized ER-in-the-Wild system architecture. In this section, we describe this architecture.

To understand our combination of PM and biofeedback, consider the following scenario. According to the PM, emotion regulation often involves several iterations of identification, selection and implementation stages. Imagine a person has identified a need to regulate some emotion, for example, anger. This is the first stage of PM. She selects a strategy, say rumination, and begin to implement it. Periodically, she will monitor how well rumination is working, via interoceptive input to the brain. Based on this, she will make one of three choices: to continue with the rumination strategy, to abandon rumination and adopt a more contextually appropriate strategy (for example, reappraisal), or to stop because either she has reached her desired emotional state or has decided to quit altogether. From this perspective, using biofeedback to assist in emotion regulation can be thought of as partial externalization of the ongoing monitoring stage of PM. With biofeedback, the changes in the undesired emotion (e.g., its intensity, duration, type, etc.) induced by strategy implementation are perceived through changes in the person's internal (physiology) or external (behavior, facial expressions, or body language) experiences and communicated through sensory modalities (visual, haptics, audio) rather than using the path of interoceptive signals. Thus, our architecture reflects both the mental processes of the person undergoing ER and the interventions that augment the interoceptive signals. In Figure 1, we illustrate both of these paths.

At a high level, an ER-in-the-wild system supports two abstract functions: detection and intervention. These functions are included in the Intelligence component in Figure 1. Each intelligence component is comprised of four parts, corresponding with the four stages of the PM model: predicting whether an emotion needs to be regulated or not (part 1); if so, predicting a contextually appropriate ER strategy that would maximize the likelihood of the user in achieving their goals (part 2); if feasible, predicting what involvement guidance may assist the user to implement that tactic effectively (part 3); and predicting what type of feedback helps the user to achieve their desired emotional state efficiently (part 4). For now, we assume that each of these parts operate independently and in principle, can be activated by the user's own decision making, but eventually one can imagine that they operate in concert.

Intervention can be one of three types–cueing, involvement, and feedback–reflecting the degree to which the system is involved with the user. A cueing intervention notifies user of some situation or desired action. If the involvement guides the user through a tactic, then we call it an involvement intervention. If the involvement uses sensor-derived information to assist the user to achieve their desired emotional state, then we call it a feedback intervention.

Cueing arises in parts 1 and 2: notifying a user of the need for ER and directing a user towards some strategy. Cueing is stateful: the intervention is based on the values reported by the sensors. A limitation with cueing is that it leaves the onus of taking action on the user. For example, when cueing is used to notify the user with the need of ER, it is up to the user to select an appropriate ER strategy, implement it, and to monitor how well she succeeds in regulating her emotions. The challenge of cueing is in the predictor (how can it determine the need for ER?) as well as in how the information can be easily encoded given the physical limitations of the device performing the intervention.

Involvement arises in part 3: guiding a user through the implementation of a strategy. Some challenging problems of involvement interventions are: what are the characteristics of an actuator-generated effect that makes it suitable as an involvement intervention, and what are appropriate body sites to place the actuators given the nature of the strategy?

Feedback arises in part 4. Feedback, like cueing, is inherently stateful. The challenging problem of feedback is in the predictor itself. For example, before the user engages in implementing a strategy, is the user meeting the requirements of the strategy? During implementation, how well is the user attending the strategy, and how can the user do better? How well is the user doing in achieving the desired emotional state and their motive for ER? Should the user switch to another strategy?

For the rest of Figure 1, on the left is the user who wishes assistance in regulating their emotions. The user wears an affordance [1] that is equipped with sensors to measure their physiology and collect relevant contextual and external body information (e.g., behavior, body language, etc.) . This data flows to the Intelligence components, which are

[1] An affordance could also be a mobile nonwearable device or even a stationary smart devices that the user interacts with (e.g., a smart chair).

distributed throughout the ER system architecture: at the affordance, in the mobile devices, and in the cloud. The collection of Intelligence components converts the information from the sensors, as well as the user's ER beliefs and abilities, the user's emotion goals and motives, and information from the user's clinicians and trusted family and friends, into knowledge. Based on this knowledge, commands are created and flow from the Intelligence components to the user via the wearable affordance, which generates the interventions using the actuators.

Any realization of this architecture may not include all of these data sources and components. In addition, there are system issues associated with the placement of information collection, information extraction and action determination with respect to the affordance, mobile devices and cloud, including power consumption, fault tolerance, privacy, and affordance weight. For example, it may prove a better design to have intervention selection done by the user's mobile device rather than by the wearable affordance because of power, computational, and information needs.

We briefly describe three systems in terms of our model. In these three examples, all interventions are haptic. The choice of modality—visual, auditory, haptic—depends both on user differences and on the requirements of the intervention itself. Haptics is a reasonable choice for ER-in-the-Wild because it is less conspicuous: there is a utility in ER assistance being confidential.

An interesting example of a breathing system with cueing intervention is Spire[15]. Spire is a wearable device that detects overbreathing patterns via accelerometers and gyroscopes, which it classifies into the three classes of stressed, calm, and focused breathing. The cueing haptic effect notifies a user with the need for ER but does not direct a user towards any particular strategy. The Spire smartphone app allows the user to personalize the intensity of the haptic effects as well as under what conditions the user should be cued. The Apple Watch/WatchOS 3 Breathe app is a commercial product [2] that has a breathing pacer haptic effect. The haptic effect is an involvement intervention: it guides a user through paced breathing. The effect is not personalizable, however; the user cannot change the intensity of the effect, or adjust the breathing pace, or the inhalation to exhalation ratio to their resonant frequency of breathing. Finally, an interesting example of the use of feedback intervention for breathing is the work by Janidarmian et al. [8]. This work produced an affordance based on a protocol that first measured a client's baseline breathing pattern using accelerometers on the abdomen, and then alerted the client in real-time, using haptics applied around lower back body region, when their breathing deviated from the baseline. The feedback intervention informs the user how to improve during breathing; the strength of the haptic effect indicated the degree to which the current breathing differed from the baseline. Their approach assumes the baseline breathing is the ideal, which in fact may not be the case, thus missing an educational opportunity for training on how to breathe correctly.

These three examples illustrate the utility of thinking about intervention type, in that it assists the designer in thinking in terms of the ER model, as well as the desired characteristics of each intervention.

Discussion

The architecture described here provides general understanding of ER-in-the-Wild systems as well as the design of interventions. There is a larger conversation, outside of the scope of this architecture, around unintended consequences of such technology as well as issues of social good. Given the importance of the problem of ER-in-the-

Wild and current market forces that lead to faster time to market, the time is now for a strong basis for understanding ER-in-the-Wild.

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REFERENCES

1. 2breathe. http://2breathe.com/how-it-works/.
2. Appleinsider. http://bit.ly/28WTd78.
3. Ruben T Azevedo, Nell Bennett, Andreas Bilicki, Jack Hooper, Fotini Markopoulou, and Manos Tsakiris. 2017. The calming effect of a new wearable device during the anticipation of public speech. *Scientific Reports* 7 (2017).
4. Jean Costa, Alexander T Adams, Malte F Jung, François Guimbetiere, and Tanzeem Choudhury. 2016. EmotionCheck: leveraging bodily signals and false feedback to regulate our emotions. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. ACM, 758–769.
5. Doppel. http://www.doppel.london/.
6. James J Gross. 2014. *Handbook of emotion regulation* (2 ed.). Guilford publications, Berlin; New York.
7. James J Gross. 2015. Emotion regulation: Current status and future prospects. *Psychological Inquiry* 26, 1 (2015), 1–26.
8. Majid Janidarmian, Atena Roshan Fekr, Katarzyna Radecka, and Zeljko Zilic. 2016. Haptic feedback and human performance in a wearable sensor system. In *Biomedical and Health Informatics (BHI), 2016 IEEE-EMBS International Conference on*. IEEE, 620–624.
9. Myounghoon Jeon. 2017. *Emotions and Affect in Human Factors and Human-Computer Interaction*. Academic Press.
10. David Kotz. 2017. Challenges and Opportunities in Wearable Systems. (2017). https://dl.acm.org/citation.cfm?id=3089821 Workshop on Wearable Systems and Applications keynote presentation.
11. David Kotz, Kevin Fu, Carl Gunter, and Avi Rubin. 2015. Security for mobile and cloud frontiers in healthcare. *Commun. ACM* 58, 8 (2015), 21–23.
12. Pardis Miri, Robert Flory, Andero Uusberg, Helen Uusberg, Gross, James J., and Katherine Isbister. 2017. HapLand: A Scalable Robust Emotion Regulation Haptic System Testbed. In *CHI'17 Extended Abstracts on Human Factors in Computing Systems*. ACM.
13. Heather Culbertson Robert Flory Helen Uusberg James J. Gross Keith Marzullo Katherine Isbister Pardis Miri, Andero Uusberg. 2018. *Emotion Regulation in the Wild: The WEHAB Approach*. Technical Report. University of California, Santa Cruz. https://www.soe.ucsc.edu/sites/default/files/technical-reports/UCSC-SOE-18-04.pdf.
14. Mark S Schwartz and Frank Andrasik. 2015. *Biofeedback: A practitioner's guide*. Guilford Publications. 36–37 pages.
15. Spire. https://spire.io/.